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Determining Groundwater Flux from Temperature Variance

James Cope
University of Nebraska-Lincoln

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by

James Cope

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Determining Groundwater Flux from Temperature Variance

James Cope, B.S.

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Advisor: Katie Cameron

The purpose of this research is to identify the underlying cause of the atypical temperature oscillation of groundwater temperature within the Ashland-1 nesting well site. Groundwater in this area experiences temperature peaks within the 50-ft screened well, while temperature data from the 15-ft screened well experiences a lesser range of temperature fluctuation . The first phase of the project involves gathering data from these nesting wells can comparing that data to surface water temperature data taken from a USGS gauging station. The second phase was to associate these temperature oscillations with possible geological factors that could be driving this temperature fluctuation. The final phase involves reviewing the thermal data gathered to form a correlation between groundwater inputs by the thermal data gathered. . By identifying that the use of groundwater thermal data as a mean of determining groundwater inputs we will have created an additional means of assessing groundwater inputs.

INTRODUCTION

The need to know where the groundwater we use is very important because without that information it is hard to make policies to properly delegate water resources. The process of finding the source of surface water is easier because it is visible without the need of geological exploration but, assessing the inputs of groundwater requires additional scientific research and time. The main reason is that there is a need for information on the geology of the area, which is often poorly understood at the level of detail required to understand the complex connection between surface water and groundwater. This complex interactive system requires a significant amount of scientific research to obtain a definitive answer on how surface water and groundwater are connected. This complexity causes dissidence between people who consume groundwater in excess and negatively effect affect those who rely on surface water within the same area. An additional analytical method is needed in order to balance the usage of surface and groundwater consumers is a fair and balanced manner.

Comment [KC1]: Maybe say something more like a need for balance between SW and GW user demands, maybe mention quality too because understanding movement of groundwater and interaction with surface important for that, just ideas.

Other than precipitation there are two more major factors that influence groundwater systems. One of those factors is from a losing surface water system, where the surrounding groundwater level is lower than the water level in the surface water source (river, water body) it is in contact with. This causes the surface water to lower because it is attempting to form equilibrium with the surrounding, lower groundwater.

The second factor that influences groundwater is the addition of water from far off groundwater sources. One large issue with this type of recharge is that it can be much slower than recharge from surface water sources , movement of groundwater recharge into the state of Nebraska can vary based on a multitude of hydrogeological factors . For that reason this slow moving water does recharge Nebraska's groundwater, but at a much slower rate than local surface water and precipitation. Groundwater systems in Nebraska that are recharged from a non-local area are at risk of over consumption because of the slowed recharge rate.

The current method of determining the inputs of water is to manually gather water level data from around the area and create a map that shows the geology along with the direction of groundwater movement. The method I am hoping to shed more light on would use the temperature of the groundwater to add an additional parameter of data to help increase the accuracy of determining the sources of groundwater in a given area. Generally speaking groundwater from non-local sources has a thermal temperature that differs compared to groundwater that is replenished by local surface water and precipitation. By looking at a long term trend of ambient water temperature, we could compare the current groundwater temperature to surface and non-local groundwater thermal data. With thermal data gathered from local sources would be used to create a trend in which groundwater charged by local sources would follow, and inversely groundwater that does not follow the local data trend could have inputs from a non-local source.

With more ways to determine groundwater inputs and their behavior this additional method will allow for policy makers to make more accurate decisions on the delegation of groundwater resources. With current laws, areas with low recharge rates can be overused and as a result dry up many wells within the area. But with an additional way to look we can determine the origin groundwater and recharge rates with greater accuracy. With this greater accuracy in determining source water it will also help areas that have a very large percentage of surface water input because, it will allow those areas increased water use because the recharge rates are much higher within those areas. Within this research paper I will predominantly be looking at hydrographs showing the level of head water within a system along with temperature data at

Comment [KC2]: Wording, I know what you mean

Comment [KC3]: Be more steady and representative of the non-local source inputs

Comment [KC4]: Wording I know what you mean

Comment [KC5]: These are great points different time? Seasonal? increments. I will use that data to show the direction of groundwater movement throughout the area and relating that back to the thermal data.

Freeze, R. Allan., and John A. Cherry. Groundwater. Englewood Cliffs, NJ: Prentice-Hall, 1979. Print. This book is where I derived the majority of my knowledge of groundwater interaction with surface water. This book going into some detail of groundwater flow based on permeability of the geology the groundwater is flowing through. With the information presented within this book I was able to identify the gradient of flow and formulate possible reasons for the wider range of thermal data within the 50-ft screened well.

In conclusion, I will be looking at thermal and water level data within the Ashland-1 Papio-Missouri River NRD well site with the intention of relating surface water infiltration to the temperature of the groundwater. Increasing the amount of parameters to determine groundwater inputs would benefit a large percentage of people who rely on groundwater by, allowing policy makers to have additional data to consider when delegating water rights. It would allow for an alternative method of determining areas that have a faster recharge rate compared to other areas. This knowledge will hopefully be used to effect or update current policies that deliberate groundwater and surface water distribution throughout Nebraska. This method of looking at the temperature of the groundwater and comparing it to the temperature of the local surface water temperatures will hopefully be an alternative approach determining the recharge rate of groundwater.

Comment [KC6]: Alternative/supplemental maybe, areas under the centrals parts of uplands will all just have same constant value in each well except perched wells which sometimes do have a trend but I can't pin down how or why those upper layers do that

Materials and Methods

The steps taken to investigate the correlation between groundwater and surface water began with finding pre-existing groundwater testing holes that contained a monitoring unit that could gather temperature data along with current wellhead data. The site located at (41° 6'29.90"N 96°18'53.31"W) is a groundwater monitoring well owned by the NRD referred to as Ashland1. This site was referred based on its counterintuitive temperature flux throughout the year within the 50ft well data (warmest during the winter and coldest during the summer).

Ashland1 is a nest of 4 groundwater monitoring wells, each with a profile of thermistors located at pre-designated depths. Along with the thermal data, depth to water (head) data is also continuously recorded at hourly intervals . Using data collected from the testing sites using a rugged reader unit I will use the data gathered throughout the year and plot that data against data gained from the USGS surface water gauging station, used at the Platte River crossing northeast of Ashland, NE. Showing the temperature and water level of both the surface water and groundwater, along with the water head level, I will be able to determine the direction of flow in the system. Because of the unique temperature relationship between surface and groundwater this is the only well site that is within this area that follows this unique temperature fluctuation and will be the only data studied. With access to one sampling site more time can be devoted to fully understand the correlation within the water system in this area. The data is being collected by in situ level trolls equipped with thermistors to gather data on the groundwater temperature. At the Ashland-1 site there are four monitoring wells at varying depths. The wells are located at the 15ft, 50ft, 74ft, and 113ft marks but over the course of the study the in situ troll within the 113ft monitoring well was not gathering data due to an equipment malfunction.

The instruments used within the wells are a form of absolute (or non-vented) in situ level trolls. These trolls are able to log pressure data, temperature data along with water level within each of four wells in the Ashland-1 site. Along with the level trolls the NRD has placed a barometric pressure gauge within 50ft from the well site, this pressure data can be used to determine quantity the amount of head change related to changes in atmospheric pressure change and is used to adjust the water levels measured by the troll to compensate for barometric pressure changes at the site (in-situ provided correction program).

The instruments used to collect daily water temperature data within the Platte River is maintained by the United States Geological Survey. The site consists of one DCP monitoring system that collects the current water height of the Platte River, along with the current temperature of the river. The data is collected with a pressure line placed near shore of the Platte River, the DCP can used the resistance in pressure to accurately extrapolate the current water level and discharge (flowrate of river water moving past the gage site location).

Data gathered will then be put into an excel spreadsheet where temperature and level of the Platte River will be plotted alongside of the groundwater temperature and water level at Ashland-1. The graph produced will show the vertical direction of flow within the groundwater system by depicting whether the heads indicate a gaining versus losing scenario for each of the well screened intervals over time. In addition,with the graphs will show how the direction of flow relates to the temperature change within the groundwater system. Using these graphs I will form a correlation between the direction of flow and the change in temperature based on that gaining or losing scenario as they relate to the different geologic formations screened.

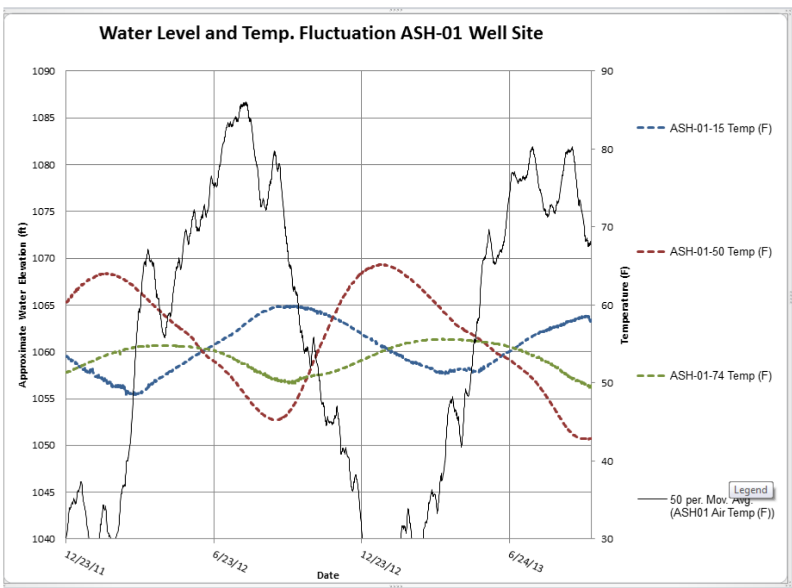
Comment [KC7]: This will only tell you the river is flowing south if you were using the 15 ft well as comparison with the downstream river level elevation. WAIT… I get it you mean vertical flow just at ASH01? Right see if this is what you are saying…

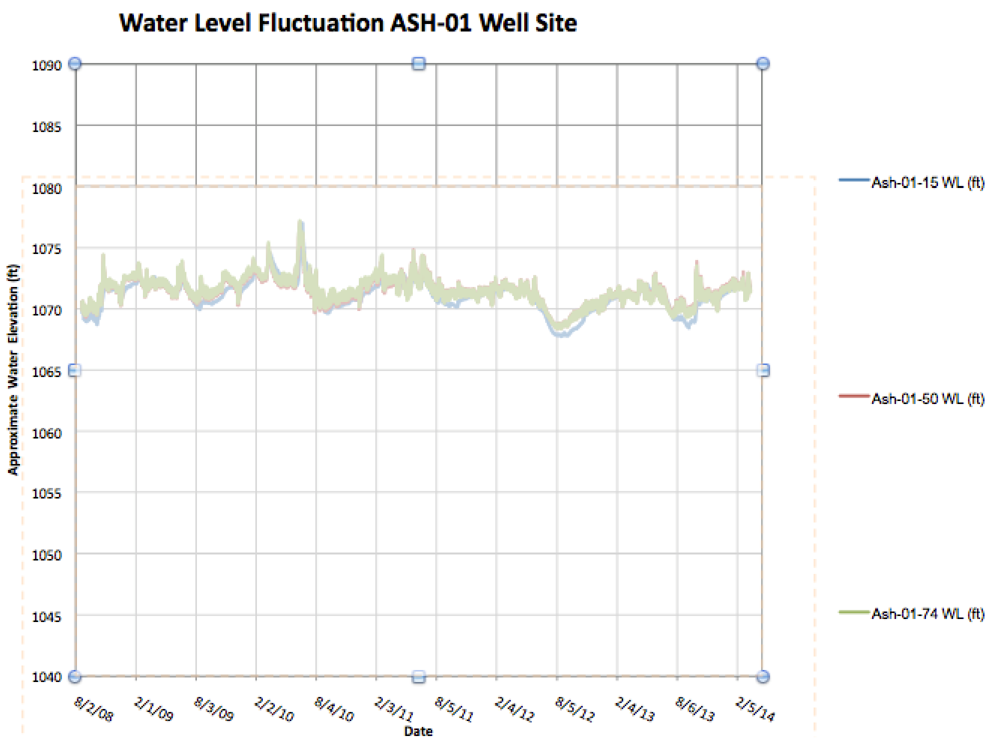
Comment [KC8]: Maybe say something that ties back to the recharge concept you outlined in the intro like furthering understanding of flow shows us pathways for the surface water to influence groundwater

RESULTS

To form a correlation between groundwater and surface water temperature I used data gathered from the Ashland-1 well site, within each well is one in situ level troll located at the following depth intervals: 15, 50, and 74 feet. I used the groundwater thermal data at

Ashland-1and overlaid it with thermal surface water data gathered from the USGS Platte River gauging station to show how the surface and the groundwater elevations and temperatures are connected. Used the well head level data taken from the four well sites to show the vertical direction of groundwater motion within the local area. Determined which geological horizons were being most affected by surface water based on both the direction of groundwater motion and the thermal range of each depth interval .





The data above in Figure:1 shows that there is a correlation between the surface water and the groundwater within the 15ft, 50 ft and 74ft wells. The most major distinction is that at the 50ft depth the temperature data seems to be further offset and experience the highest water temperature per year during the peak of oscillation, during the days of the year that have the lowest level of air temperature. As depth increases the timing of the temperature oscillation is offset further in the year relative to the depth screened. The temperature flux that shows the highest range of flux is the ASH-01-50 line, which shows the peak temp of the groundwater at 50 feet, is the highest during February (almost 65F) and the lowest (just over 40F) being in June.

Above in Figure: 2 contains the water level data within each of the nesting wells, this well water level data corresponds directly with the water level of the Platte River. This water level data shows the vertical direction of the water movement throughout the system and shows the upstream Ashland-1 groundwater elevations as higher than the downstream river level as expected. The data shows that in all three of the sites that are collecting data that water levels remained fairly even showing that the majority of water movement is in the lateral direction and generally follow the river level fluctuations. However, subtle differences in hydraulic head shown for the nested wells indicate vertical components for the flow system, including gaining/losing scenarios for the river and different geologic units screened.

Comment [KC9]: May need another figure here showing a close-up of the water levels over like a month time and caption to explain maybe also add gaining and losing elevation table alongside it – see email

DISCUSSION

The thermal data show in figure:1 shows that within the 50 ft zone of the test site that there is an atypical range of thermal data trend. Thermal maximums occur during the winter when the groundwater temperature should be decreasing. The water level data from the same test sites shows that there are seasonal trends of subtle differences in head indicating vertical water movement in each of the three wells (refer to figure X). Although the majority of water motion is occurring horizontally as the river and adjacent groundwater in the valley flows downstream (surface and groundwater flow are typically driven by topography), , the vertical differences in well head elevations at the 15, 50 and 74 feet depths indicate that the river is a generally losing surface water to the groundwater units in the spring, gaining water from the groundwater in the summer, and the sand and gravel formations at the 50 and 74 foot depths are generally losing to both the shallower and deeper depths in the fall.

Comment [KC10]: See my email attachments I don't know how much you want to get into this, there are equations and theories about hydraulic head you can look up about gaining and losing. I can't remember what all I sent you on that USB..

This atypical thermal range could be caused by the sandy layer located at the 50 ft monitoring well being recharged by a non-local source. Being recharged at a different location then flowing into the testing site would explain the increased delay for the 50 ft well to experience its large thermal flux during days when the air temperature is at its lowest point.

Comment [KC11]: I need to think about this more – 15 footer peaks at top temp, then 50 footer peaks at top temp, then 74 footer peaks like you would think it should with distance from the source of the flux (air to SW to GW pathway). I am not getting what you are saying here

Groundwater temperature data in the 15 ft, 50-ft, and 74 ft wells follow the general thermal trend as the Platte River temperatures make a full oscillation up and down on a seasonal one year scale period while being offset by the depth of the sensor meaning, the temperature peaks for each well, which come subsequent to the river temperature peaks, occur later and later in time as you increase with depth and distance down from the surface water source. The sensor located within the 50 ft well follows this trend but has a wider range of temperature fluctuation leading to the assumption that groundwater within this horizon is being recharged by the same local source but something is amplifying the temperature range. The source area recharging the sandy layer screened at 50ft could be an area that is more affected by the daily and/or seasonal temperature changes. Water that has been heated will hold on to its amount of thermal energy longer because of waters naturally high level of specific heat. This allows the slow moving groundwater to keep its level of energy while being Not sure where you are going here but yes we need to tie it back to purpose and source of water but I like where this is going.

Comment [KC12]: need to explain this more – offset?

Comment [KC13]: it is being recharged by the river 100 ft away, just why it takes 6 months is the wierd part – do you have k values for the screened intervals? I need to think about this longer and will look again here.

CONCLUSION

In conclusion the combination of thermal data within the 15-ft, 50-ft, and 75-ft Ashland-1 and the water level data, was used to demonstrate that information on groundwater inputs can be derived from thermal data. The thermal data was gathered with four nesting wells located north east of Ashland, NE. The site is set up with four separate wells screened at different depths, those depths being 15-ft, 50-ft, 75-ft, and 113ft. Although throughout the data collecting process the well being screened at 113-ft was faulty and unable to collect data. With the data that was available to me through the NRD along with the USGS I was able to show through water level data that there is very little vertical movement of groundwater from the consistency of the water

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levels. Thermal data in the testing sites shows a large discrepancy within the 50-ft well, this larger thermal flux is being driven by the recharge occurring further away from the testing site. With the increased permeability of the sandy layer located from 35-ft to 74-ft would increase the velocity of groundwater in the system.

Data was gathered from within four nesting wells located pn the east side of the4 Platte River, Northeast of Ashland, NE. The nesting wells are screened at a depth of 15-ft, 50-ft, 74-ft, and 113-ft. Within each well has a in situ trolls and are able to log pressure data, temperature data along with water level within each of the wells. The data gathered was placed within an excel file and plotted by date of data gathered.

From the data gathered it can be seen that thermal data that does not follow the typical can be attributed to being recharged from a non-local source. My data shows that within the 15-ft and the 75-ft well sections to follow a similar trend of the thermal peak being offset further as depth increases. The atypical temperature ranges occurring in the 50-ft screen well illustrates the idea that groundwater being sampled from this area is being recharged from a non-local source.

If this research project were to be repeated having a greater knowledge of hydro-geology would be the most beneficial change. Along with the funds to add additional nesting wells within the geological area to compare the movement of the thermal gradient.

REFERENCES

Freeze, R. Allan., and John A. Cherry. Groundwater. Englewood Cliffs, NJ: Prentice-Hall, 1979. Print.

Freeze, R. Allan. Theoretical Analysis of Groundwater Flow. Ottawa: Inland Waters Branch, Dept. of Energy, Mines and Resources, 1969. Print.

"Papio-NRD." Ashland-1 Nesting Well Data. N.p., 1 Aug. 2014. Web. 1 Oct. 2014.

FREEZE, R. A. Theoretical Analysis of Regional Groundwater Flow. N.p.: n.p., 1968. Print.

Anderson, Mary P. Groundwater. Wallingford: International Association of Hydrological Sciences, 2008. Print.

"Louisville Surface Water Temperature." USGS Surface Water Station. N.p., 4 Oct. 2014. Web. 18 Oct. 2014.

"Groundwater Temperature Ossolation Within the Ashland-1 NRD Well." Interview by Katie Cameron. n.d.: n. pag. Print.